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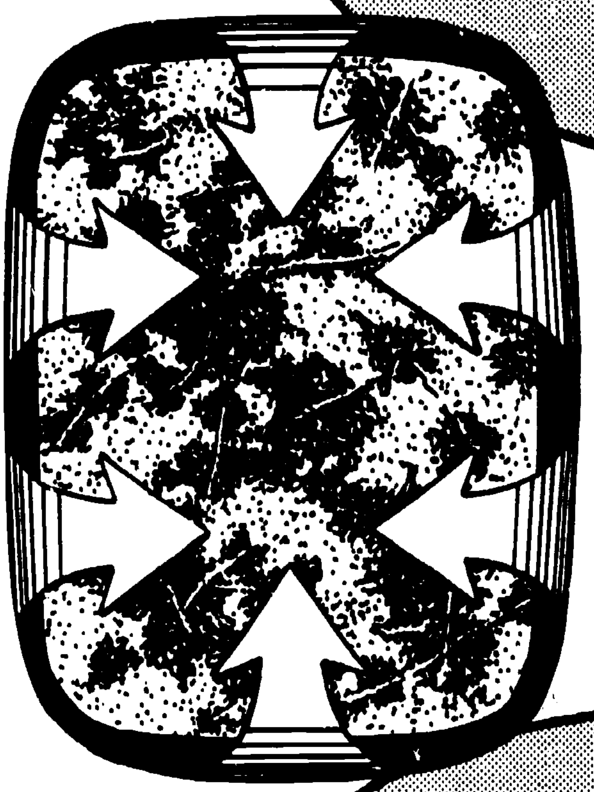
ABSTRACT

This student manual contains textual material for a two-lesson unit on activated bio-filters (ABF). The first lesson (the sewage treatment plant) examines those process units that are unique to the ABF system. The lesson includes a review of the structural components of the ABF system and their functions and a discussion of several operational modes and the conditions under which they might be used. The second lesson covers the operation of ABF systems. The laboratory tests recommended for influent and effluent monitoring are presented and related to the factors affecting biomass growth. Calculations regarding food-to-microorganism (F/M) ratio and mean cell residence time (MCRT) are presented and worked out. Plant observations and monitoring are discussed with an emphasis on awareness and identification of existing and potential problems. Some operational problems are also presented with recommended corrective measures. The manual includes a list of objectives, a glossary of key terms, a list of references, and worksheets for each lesson. (JN)

Biological Treatment Process Control

Activated Biological Filters (ABF Towers)



Linn-Benton Community College
Albany, Oregon

1984

BIOLOGICAL TREATMENT PROCESS CONTROL

ACTIVATED BIO-FILTERS

STUDENT MANUAL

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ABF SYSTEMS

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ABF SYSTEMS

Objectives

Upon completion of this lesson you should be able to do the following:

1. Describe how an ABF system differs from other secondary processes.
2. Describe the function of a reactor wet well.
3. Describe the function of the reactor.
4. Describe the construction and component parts of a reactor.
5. Describe the treatment processes that take place in the reactor.
6. Describe how mixed liquor is distributed over the reactor.
7. Describe the ABF process.
8. Recall the alternate modes of ABF operation.
9. List the operational control tests used in the ABF process.
10. Calculate pounds of food in the system.
11. Calculate pounds of bacteria in the system.
12. Calculate MCRT.
13. Calculate the F/M ratio.
14. Determine wasting rates using the F/M ratio.
15. Determine wasting rates using the MCRT method.
16. Describe the effects of nutrient deficiency on the system.
17. List the monitoring parameters.
18. List the Process Operating Parameters.

ACTIVATED BIO-FILTER

Glossary

biofilm - the biomass growing on the media

fix film growth - biomass attached to stationary substrate

media - the material (redwood) supporting the fixed film growth

reactor - the portion of the ABF system that houses the fixed film portion of the biomass

reactor recycle - the flow pumped from the wet well to the reactor

reactor wet well - a basin which serves as a pumping station as well as a collection basin: receives primary effluent, reactor effluent, and secondary clarifier sludge return

sloughed material - the biomass that continuously falls off the media small pieces at a time

THE ACTIVATED BIO-FILTER

I. THE SEWAGE TREATMENT PLANT

A. THE PLANT

The ABF plant has many of the same plant components that typical secondary systems have.

B. UNIQUE COMPONENTS

1. The Reactor Wet Well.

The reactor wet well is a pumping station as well as a collection basin. Primary effluent, reactor effluent, and secondary clarifier sludge return, all enter the reactor wet well continuously. At the reactor wet well the reactor effluent contributes the bulk of the dissolved oxygen that is needed for biological decomposition. The bacterial population in the reactor effluent is acclimated and highly active at this point. The reactor effluent material is the active mixed liquor portion of the system. The concentrated bacterial material that is returned from the secondary clarifier is important in controlling the mixed liquor concentration in the secondary system.

2. The Reactor.

The fixed film portion of the ABF system grows on wood lathes (usually redwood) in the reactor. The fixed film organisms utilize the food from the waste stream as it passes through the reactor.

The ABF mixed liquor, which is composed of suspended growth organisms and sloughed fixed film organisms, absorbs, oxidizes and metabolizes the organic food in the waste stream which is measured as BOD. The suspended growth organisms provide additional organic removal by supplementing the fixed film growth removals in the reactor.

The reactor influent is a mixture of organic food, which comes from the primary effluent; and return sludge, which comes from the secondary clarifier. As soon as the food and bacteria come into contact with one another in the reactor wet well, metabolism of the organic constituents by the bacteria will begin if sufficient oxygen and nutrients are present. This is normally the situation in an ABF system with normal domestic wastes. Biological oxidation of organic material begins in the wet well and continues as the mixture is pumped to the top of the reactor. The material is spread over the surface of the reactor media in principally two methods. In some cases fixed nozzles of various types are used. In other plants rotary distribution systems are employed.

3. The Secondary Clarifier.

The secondary clarifier serves the same purpose in the ABF plant as in other types of secondary treatment, i.e., activated sludge plants. The only significant difference is that the return sludge is returned to the reactor wet well instead of other process units at the front end of the plant, i.e., headworks or aeration basin. The return sludge is a major parameter in controlling mixed liquor concentrations in the secondary system of the ABF plant.

II. THE ABF PROCESS

A. THE PROCESS

The ABF process is a unique blending of conventional fixed and suspended growth treatment processes. An activated sludge plant (suspended growth) consists of primary treatment of raw sewage, an aeration basin and a clarifier system. The settled sludge from the clarifier is returned to the aeration basin. A conventional trickling filter system (fixed growth) has a primary clarifier, a trickling filter (usually containing rock media), and a final clarifier. In this case there is no return sludge from the clarifier. The ABF process incorporates both A.S. and T. F.

processes into a single treatment system. The raw sewage is pretreated, then proceeds to the reactor wet well. The material in the reactor wet well is a mixture of the concentrated biological solids from the secondary clarifier, reactor recycle, and the food source from the biosystem which comes from the primary clarifier. The principal function of the reactor recycle is to insure that there is a sufficient wetting rate in the reactor. This material is pumped to the reactor, at which point the waste is aerated and biologically treated by the fixed film organisms in the reactor. The arrangement of horizontal ABF media consists of individual racks made of wooden lathes fixed to supporting rails. The lathes and rails are sized to permit free movement of liquid and air in all directions. The open, horizontal configuration of the reactor media presents the optimum surface for promoting fixed film biological growth and, at the same time, prevents ponding or bridging. Oxygen transfer is provided by the dual action of the water continually moving in a film across the biota and splashing between layers. The splashing action, a repeated fracturing and reforming of drops as the wastewater falls from one layer to the next, provides additional aeration of the waste.

The reactor effluent is split, a portion returning to the reactor wet well and the remaining portion proceeding to the short-term aeration basin where further biological treatment occurs. The short-term aeration effluent proceeds to the secondary clarifier at which time the solids/liquid separation occurs. The final effluent then continues to the chlorine contact chamber. The settled sludge in the secondary clarifier is returned to the reactor wet well with a portion of this material going to waste.

B. ALTERNATE PROCESS MODES

Another mode of operation is identical to the conventional ABF process except that the reactor effluent goes directly to the secondary clarifier, circumventing the short-term aeration. There are several reasons why this mode of operation can be used. First, if the wastewater strength is low and the liquid temperature is

warm, the effluent quality may be achieved without the use of the aerator. This is an energy-saving step. If maintenance is required on the short-term aeration, it can be circumvented temporarily until the job is completed. Also, if the waste sludge system fails, short-term aeration can be used as an aerobic digester until the sludge waste equipment can be repaired. The reactor recycle still returns to the reactor wet well as does the secondary clarifier sludge return.

A third mode of operation is a high-rate trickling filter followed by short-term aeration. In this mode the reactor recycle still returns to the reactor wet well but the sludge return from the secondary clarifier returns to the short-term aeration basin. In this mode of operation there is no suspended growth mixed liquor going over the reactor. Reduced plant performance can be expected in this mode of operation.

A fourth mode of operation is that of a roughing filter followed by short-term aeration. In this case there is no reactor recycle, and the secondary clarifier sludge is returned to the short-term aeration basin. Operating the filter without sludge recycle does not take full advantage of the removal capabilities of the reactor.

C. METHODS OF PROCESS CONTROL

There are two common procedures available to the operator for controlling the process of the ABF system. One is the food-to-microorganism ratio (F/M) and the other is the mean cell residence time (MCRT). The operator can achieve a good effluent by controlling the F/M ratio or the MCRT of the system. Since F/M and MCRT are related to each other, the choice of which way to operate the wastewater plant is up to the operator. In either case, the definitions of MCRT and F/M must be redefined for the ABF system.

The reactor is a fixed film system much like a trickling filter and the aeration basin is like the activated sludge system. At present it is not possible to determine the F/M ratio or the MCRT

of a fixed film system such as the reactor. The F/M ratio, however, and the MCRT are well established in conventional activated sludge operations. To operate the ABF system by the F/M or the MCRT method, only a portion of the biosystem is used in the calculations; specifically, the short-term aeration basin. In the case of the ABF system, the F/M ratio will be much higher than conventional activated sludge, usually in excess of 1.0 and the MCRT will be of much shorter duration than conventional activated sludge, usually in the neighborhood of one and one-half to three days.

Food to microorganism ratio (F/M) is defined as the pounds of BOD (food) entering the secondary system each day divided by the pounds of mixed liquor volatile suspended solids (microorganisms) in the aeration basin.

To determine pounds of food:

lbs Food = Q (Flow/Day, MGD) X Pri. Eff. BOD (mg/l) X 8.34

To determine pounds of microorganisms:

lbs MLSS = Aeration Basin Volume (MG) X MLVSS (mg/l) X 8.34

To determine F/M ratio:

$$\text{F/M Ratio} = \frac{\text{lbs. Food/Day}}{\text{lbs. MLSS}}$$

Mean cell residence time (MCRT) and sludge age are the same thing. Both represent the time required, in days, to theoretically change the microorganism population completely in the aeration basin. This is determined by dividing the pounds of mixed liquor volatile suspended solids (MLVSS) in the aeration basin by the pounds of MLVSS wasted each day.

$$\text{MCRT} = \frac{\text{lbs. MLVSS in Aeration Basin}}{\text{lbs. MLVSS Wasted per day}}$$

MCRT and sludge age are in days.

By establishing a facility control point for the F/M ratio or the MCRT, the operator can accomplish the desired effluent quality in his facility. Since both F/M ratio and MCRT are directly related, controlling one actually controls the other. Both techniques are good tools to control the mixed liquor quality, regulate the growth of the biological system and get good organic food stabilization during the process, giving a good final effluent. In both procedures the solids level needed to stabilize the organic food is established and the operator should attempt to maintain this within a relatively narrow range until environmental changes indicate otherwise. Both operating parameters are controlled by wasting the excess biomass produced upon metabolizing the organic wastes entering the secondary system.

D. NORMAL OPERATION - F/M PROCEDURE

To operate the ABF system by the F/M ratio procedure the operator must know how much food (BOD) is entering the secondary system and how much biomass is present in the short-term aeration system. Both of these parameters in the F/M operation process present some difficulty. First the BOD test is a five-day analysis and the operator is determining the F/M ratio five days too late. The VSS in the biomass is a variable quantity and does not represent all active bacteria. Consequently, the F/M method of operating a wastewater facility is subject to errors which only plant operating experience can overcome.

Let us assume an example, for clarification, of operating a facility by the F/M procedure:

Avg. Flow	=	1MGD
Primary Effluent BOD	=	150 mg/1
MLSS	=	3,500 mg/1
MLVSS	=	2,800 mg/1
Aeration Volume	=	0.045 Million Gal.

F = lb. BOD = 1 MGD X 150 mg/1 X 8.34 = 1,251 lb. BOD

M = lb. VSS = 0.045 MGal. X 2,800 mg/1 X 8.34 = 1,059 lbs. VSS

$$F/M = \frac{1,251}{1,051} = 1.19$$

It must be remembered that the F/M ratio is higher than the conventional A.S. F/M ratio because we have not accounted for the biomass of the fixed film in the reactor.

To maintain solids levels in the short-term aeration basin, the operator must waste all of the excess solids produced through biological metabolism in the secondary process. To do this accurately, the primary effluent and secondary clarifier effluent BOD values must be known. Waiting for five days for BOD results is obviously inconvenient and too late to properly waste solids from the system. By estimating the pounds of BOD removal in the secondary system (previous BOD data), the operator can be fairly accurate in calculating the amount of solids to be wasted from the system and maintaining the proper solids level in the aeration basin.

Another required parameter is the VS concentration of the return sludge. This return sludge is in a concentrated form and is the most obvious source to waste from. Let's establish an example for the wasting procedure when the plant is operating by the F/M method. We will use the same values as in the previous example:

Avg. Flow	=	1 MGD
Prim. Eff. BOD	=	150 mg/l
MLSS	=	3,500 mg/l
MLVSS	=	2,800 mg/l
Aeration Vol.	=	0.045 MGal.
Eff. TSS	=	20 mg/l
Eff. VSS	=	15 mg/l
Excess Sludge Prod.	=	0.065 lb. VSS/lb. BOD Removal
Eff. BOD	=	20 mg/l
Waste Sludge Conc. (TS)	=	10,000 mg/l (1%)

lb. BOD removed = 1 MGD X (150-20) mg/l X 8.34

= 1,084 lb./day

VSS produced = 1,084 X 0.65 = 704 lb./day

Eff. VS = 1 MGD X 20 mg/l TSS X 8.34 X 0.75 lb. VSS/1 lb. TSS

= 125 lb./day

VS = 704 lb./day - 125 lb./day = 580 lb./day at 10.000 mg/l TSS conc. in return sludge.

$$\text{Waste Vol.} = \frac{580\ \text{lb.} \times 1{,}000{,}000}{10{,}000\ \text{mg/l} \times 8.34} = 6{,}955\ \text{gpd}$$

Now that the amount of waste material has been determined, a daily wasting schedule must be developed. The most undesirable procedure for wasting biological solids from a secondary system is called slug wasting. This is done by wasting all of the solids in a short period of time. The effect of slug wasting is, in actuality, overwasting. In a large facility where there is 24-hour operator control, the waste sludge program is usually carried out on a continuous basis. In smaller plants in which there is only one shift coverage, the wasting program must be carried out either continuously or in short intervals throughout the time that the operator is present. If the plant is set up with a timer control on the wasting system, the wasting program can be carried out at various intervals throughout the 24-hour period, whether the operator is present or not.

E. NORMAL OPERATIONS OF THE MCRT PROCEDURE

Control of the wastewater facility is much simpler by the MCRT procedure, since fewer parameters are required. Since MCRT and F/M are directly related, controlling the MCRT actually controls the F/M ratio. The only parameters required to be known by the operator are the aeration volume, the concentration of the MLSS, and the concentration of the secondary clarifier return sludge material. Referring back to the previous examples in the F/M control procedure, let us determine what the MCRT is:

Ave. Flow	=	1 MGD
Primary Effluent BOD	=	150 mg/l
MLSS	=	3,500 mg/l
MLVSS	=	2,800 mg/l
Aeration Volume	=	0.045 MGal.
Effluent TSS	=	20 mg/l
Effluent VSS	=	15 mg/l

Sludge Production = 0.65 lb. VSS/lb. BOD removed
Effluent BOD = 20 mg/l
Waste Solids Conc (TS) = 10,000 mg/l (1%)

MCRT = lb. MLSS in Aeration Basin/lb. Solids Wasted/Day

For a two-day MCRT:

lb. Eff. Solids = 1 MGD X TSS 20 mg/l X 8.34 = 167 lbs.

$$\text{lb. Solids Wasted/day} = \frac{0.045 \text{ MG} \times 3500 \text{ mg/l} \times 8.34}{2 \text{ days}}$$

= 657 lb./day

$$\text{Waste Volume} = \frac{(\text{Solids Wasted/Day-Eff. Solids}) \times 1{,}000{,}000}{\text{Waste Sludge Conc.} \times 8.34}$$

$$\text{Waste Volume} = \frac{(657 - 167 \text{ lb./day}) \times 1{,}000{,}000}{10{,}000 \times 8.34}$$

= 5,875 gallons

F. Another commonly accepted method of calculating MCRT is:

$$\text{MCRT} = \frac{\text{Amount of solids in the secondary system}}{\text{Amount wasted + Amount lost in effluent}}$$

Where amounts are in pounds.

All that is needed is the determination of each of these terms, plug them into the formula, and process the answer. Let's look at each term separately.

1. Amount of Solids in the Secondary System.

The most difficult component of calculating MCRT is the determination of the amount of solids you have in the secondary system. There is a fair amount of controversy over just how this might be done. The main consideration, however, is that you do it the same way every time it is calculated.

Essentially three methods may be used. Method A uses the total system.

lbs solids = (Vol of aeration + Vol of clarifier) X MLSS

Method A

Method B uses the aeration tank only.

lbs solids = Vol of aeration X MLSS

Method B

Method C is the blanket level method.

$$\text{lbs solids} = (\text{Aer. Vol X MLSS}) + [\text{Clar. Vol (Clar. Depth - DOB)}] \left(\frac{\text{RASTSS + MLSS}}{2}\right)$$

Method C

Any of the above illustrated methods are appropriate for MCRT use.

In Method A the MLSS concentration is multiplied by the total volume of all aerators and clarifiers in the secondary system.

Example:	Aeration Basin	=	0.045 MGal.
	Clarifier	=	1.0 MGal.
	MLSS	=	3500 mg/l

lbs. solids in plant = (solids in aeration + solids in clarifier) X MLSS conc.

= (0.045 MG + 1.0 MG) X 3500 mg/l X 8.34

= 30,503

Using Method B only the aeration volume is used in the calculations.

Example: Aeration Volume = 0.045 MGal.
MLSS = 3500 mg/l

lbs. solids = aeration volume X MLSS conc. X 8.34
= 0.045 X 3500 X 8.34
= 1313

F. Calculations Using Method C

In activated sludge plants, the clarifiers are often 50% or more of the total volume of the secondary system. In that case, methods A and B will give a poor estimate of total secondary system solids. Method A will underestimate total secondary system solids if the clarifier sludge blanket levels are high and overestimate total secondary system solids if clarifier sludge blankets are low. Method B will always underestimate total secondary system solids because it ignores the solids in the clarifiers.

The amount of solids in the clarifiers can be determined by using the volume of the blanket; multiply the blanket thickness by the surface area of the clarifier. This volume is then multiplied by the average of the MLSS and the return activated sludge total suspended solids to generate a figure in pounds. This figure is added to the amount under aeration.

Example: Clarifier Depth = 13 ft.
Clarifier Radius = 10 ft.
Blanket Depth = 7 ft.
Blanket Thickness = 6 ft.
Clarifier Surface Area = 314 sq. ft.

Blanket Volume = Surface Area X Blanket Thickness
= 314 $ft.^2$ X 6 ft.
= 1884 $ft.^3$
= 1884 $ft.^3$ X 7.48 $gal/ft.^3$ X 1 MG/1,000,000 gal.
= 0.0141 MG

Aeration Basin Vol. = 0.045 MG
MLSS = 3500 mg/l
RASTSS = 10,000 mg/l

$$\text{Ave. Clar. Sludge Conc.} = \frac{\text{MLSS} + \text{RASTSS}}{2}$$

$$= \frac{3500 + 10{,}000}{2}$$

$$= 6750 \text{ mg/l}$$

lbs. Solids = (solids in aer. X 3500 mg/l) + (solids in blank. X 6750 mg/.l) X 8.34

= (0.045 MG X 3500 mg/l) + (0.0141 MG X 6750 mg/l) X 8.34

= 2107.5 lbs.

G. AMOUNT WASTED

If you have a reliable flow meter, just multiply the waste activated sludge flow by the suspended solids concentration of the material wasted. If you don't have an accurate flow meter, refer back to page eight in this module and calculate waste volume as illustrated in the example problem shown.

H. AMOUNT LOST

No matter how good your effluent looks, some of the organisms are escaping from the plant via the clarifier weirs. Multiply plant [illegible] by the effluent suspended solids to determine pounds of solids lost.

Example:

lbs. Eff. Solids = 1 MG flow X 20 mg/l Eff. SS X 8.34

= 167 lbs.

NOW LET'S CALCULATE MCRT!

$$\text{MCRT} = \frac{2107 \text{ lbs.}}{580 \text{ lbs.}} + 167 \text{ lbs.}$$

$$= 2.82 \text{ days or } 3 \text{ days.}$$

I. THE MCRT METHOD OF CONTROL

By controlling the wastewater facility by the MCRT procedure, it becomes apparent that if the mixed liquor suspended solids

increases, then more solids are wasted by the operator to maintain the two-day MCRT. If the mixed liquor suspended solids decreases, then the operator would actually waste fewer solids.

The normal range for the MCRT in the short-term aeration basin of an ABF system is between 1.5 to 3.0 days. Remember, the MCRT is only an apparent MCRT since there are two biosystems in the ABF process. The MCRT of the biofilm in the reactor is much longer than in an activated sludge system.

The controlling parameter for determining the proper MCRT of any particular facility is the final effluent quality. After the wastewater facility is operational and a mixed liquor system has been established, the operator should determine the best MCRT for the facility by establishing an MCRT, operating it for two to three weeks, and then changing the MCRT and running for two to three weeks, etc. This can be done several times to determine the optimum MCRT range for the plant in a relatively short time (two to three months).

If the MCRT is too short, the effluent quality will deteriorate, since the biological system might not be adequate for the food coming into the system. The effluent BOD and TSS would be higher than desired since the young mixed liquor system would not be completely oxidizing the food.

If the MCRT is too long, the mixed liquor suspended solids concentration would be high. This could result in excess biological population for the food entering the system and poor settling will occur. Because of the high numbers of bacteria present in relationship to the food entering the facility, the mixed liquor system would be operating for the most part in the endogenous respiration zone.

J. MIXED LIQUOR IDENTIFICATION

The ABF mixed liquor system is normally darker in color than that of a conventional system. This is due to the sloughed material from the reactor, which typically has a long MCRT. The biofilm in

the reactor is a light brown to gray color, but the material underneath this biofilm is dark brown to black. The sub-biofilm coloration is typical of fixed film systems. If a high hydraulic load is experienced by a facility, the mixed liquor system may become slightly darker than normal due to the increased hydraulic flow through the reactor, which will increase sloughing temporarily. Typically, the ABF mixed liquor is a dark chocolate brown color and the return sludge from the clarifier may be slightly darker in appearance. The odor of the ABF mixed liquor is that typically identified in conventional A.S. systems as a musty or humus odor.

Septic sludge occurs in the secondary clarifiers and is caused by excessive detention time of the settled sludge in the clarifier. It is characterized by the color of the return sludge going from dark brown to black. The humus odor changes to a sour or rotten egg smell and the appearance of the floc becomes very dispersed with very little flocculation. To correct an anaerobic or septic sludge condition, the operator must increase wasting rates and/or increase return sludge rates to correct for the excessive detention time of the mixed liquor population in the secondary clarifier. If the operator monitors the secondary clarifier sludge blanket depth, he would be able to detect an excessive depth of the sludge in the clarifier. Any time the operator sees an indication that this may be occurring, increased monitoring of the clarifier return sludge concentration, return sludge rate, sludge blanket depth, and wasting rates should begin.

K. BULKING SLUDGE

If the operator notices a sludge blanket rise in the secondary clarifier with a subsequent lighter color of the mixed liquor, he should suspect food overload or excessive wasting of the mixed liquor. To confirm his suspicions he should take a sample of the mixed liquor and the return sludge and perform a settleometer test on the mixed liquor. He should also run a spin test on the mixed liquor and the return sludge to determine the approximate solids concentration.

If the mixed liquor settles significantly less than normally expected, the operator can assume that he is now dealing with a younger sludge which does not flocculate well. Young sludge contains a considerable amount of bound water in the biomass and does not settle well.

If a shock load of food has entered the secondary system, the spin test will show that the mixed liquor concentration has stayed about the same, with a decrease in the return sludge concentration. The return sludge will show poor settleability and sludge compaction will be poor in the clarifier. If this condition is occurring, the operator should check the aeration basin for low residual D.O. and check the biological respiration rate since it will probably be markedly higher than normal. This condition is usually temporary with a short period of poor effluent quality in the secondary clarifer effluent. To correct this condition more rapidly, wasting should be stopped temporarily and the return sludge rate to the reactor wet well should be increased. This will increase the bacterial contact with the food entering the secondary system. This condition is usually associated with pin floc carry-over in the secondary effluent. This pin floc is very light in color, has a high BOD, and a relatively low suspended solids weight.

The same condition as above can occur if the plant operator inadvertently overwastes the mixed liquor system with the same resultant symptoms. The same corrective measures should be taken, but it will take much longer for the effect of the corrective measures to be felt in the plant. This time lag occurs because there is a loss of mixed liquor when overwasting occurs. The mixed liquor must be reestablished before the plant recovers fully.

If the settleometer test begins to show a trend toward poor settling sludge without the color change that would normally be expected in the above stated condition, microscopic examination of the mixed liquor should show if the filamentous population has increased. When filamentous groups begin to appear in significant

numbers, some condition has caused a change so that the environment favors filamentous organisms over the usual population. Corrective measures would be to decrease wasting until the proper F/M ratio or MCRT is reached, and to increase residual D.O. to about 2 mg/l in the aeration basin.

L. NUTRIENT DEFICIENCY

Normal wastewater will have all of the necessary ingredients for good biological growth. Organic material, nitrogen and phosphorus are present in sufficient levels for good metabolic activity. If a wastewater plant receives a significant amount of wastewater from food processing industries, then the operator should be aware of the possibility of insufficient nutrient constituents. Typical areas of nutrient shortage are with the compound ammonia-nitrogen and various phosphorus compounds. If this is the case, these nutrients will have to be added to the mixed liquor system to encourage good biological growth. If the system is nutrient poor, the metabolic activity will be low (low respiration rate) and the secondary clarifier effluent will be high in solids and BOD. Ammonia-nitrogen and/or phosphorus will be absent in the effluent. Soluble BOD will be the most significant problem in this type of condition. The settling characteristics of the mixed liquor material is normally slower, but the significant characteristic of the settleometer test is that there will be poor flocculation and considerable amounts of dispersed particulates left in the supernatant.

M. PROCESS MONITORING

Monitoring parameters are BOD, total suspended solids (TSS), temperature, and pH. These parameters are normally required for monitoring plant efficiency. State and federal agencies also normally require a coliform count in the final effluent. To determine the efficiency of the primary clarifier and the secondary system, the BOD and TSS should also be run on the primary effluent. From the difference of the primary effluent and the final effluent BOD, the operator can determine how well the secondary system is operating.

To achieve a more rapid value on the secondary system efficiency, the operator can use the COD test. The normal COD analysis requires about 2.5 hours to complete. In normal domestic wastewater, the BOD value is about 2/3 of the COD value in the primary effluent stream. Obviously, the COD and BOD values must be correlated to each other to establish a wasting schedule based on the COD removed from the system.

Another parameter that is useful is the turbidity of the final effluent. There is, of course, no direct relationship between turbidity and BOD since BOD can be mostly soluble. Turbidity changes in the effluent over a 24-hour period or on grab samples throughout the daily operation can give indications of how well the process is running. If the plant has a normal diurnal flow pattern, the turbidity will probably increase slightly with increased hydraulic loading and reduce below the average at the low flow periods. The day-to-day average turbidity should stay about constant. If the turbidity increases dramatically, then the operator should suspect plant conditions that indicate process upset and attempt to find the cause of the problem so that corrective measures might be taken.

N. PROCESS AND OPERATIONAL PARAMETERS

There are several operating parameters and tests available to the ABF plant operator. All of these tests are aimed at controlling and monitoring the mixed liquor system. The operator can determine if the mixed liquor system is healthy or if the system is changing and requires operational changes. Some tests are related to each other but are all important since the evaluation of the mixed liquor system is not determined by one analysis alone.

The mixed liquor, return sludge and waste sludge, and suspended solids should be analyzed at least once each day and directly correlated by analyzing the same sample with a centrifuge spin analysis and a settled volume in a Mallory settleometer. From the settled volume and the mixed liquor suspended solids values, the sludge volume index (SVI) can be calculated. The centrifuge spin

is used several times throughout the day to quickly determine changes in mixed liquor concentration and the concentration of the return and waste sludge. The centrifuge spin is run for 15 minutes in a 12.5 ml centrifuge tube graduated in percent with 12.5 ml equal to 100 percent. The percent concentration in the centrifuge tube is the percent value only for the volume of the tube. A five percent spin test value actually approximates 5,000 mg/l of solids concentration. The actual mixed liquor solids concentration relationship with the percent spin analysis will stay relatively close throughout any given day, although the operator might find that the relationship between the two may change from day to day.

The operator can establish a ratio for the mixed liquor system by dividing the mixed liquor suspended solids concentration by the percent value of the spin tests. The terms of the value arrived at is mg/l per percent. If the mixed liquor concentration is 4,000 mg/l and the spin value is five percent, the ratio equals 800. Values between 800 and 900 for the ratio are considered normal for mixed liquor. If the mixed liquor concentration stays the same and the spin test value increases, the compaction of the sludge is less and indicates that a young sludge is present in the mixed liquor system. Values of 500 to 600 for this ratio indicate a young sludge system. As values approach or exceed 1,000, the sludge is considered over-oxidized or old. The return sludge and waste sludge values are generally higher than those of the normal activated sludge plant. If the normal activated sludge value is 800, the return sludge value may be slightly higher (900 to 1,000).

The dissolved oxygen concentration in the reactor effluent mixed liquor is not a parameter that is readily controlled. Under normal loading and mixed liquor concentration the operator will find that D.O. concentration in the reactor effluent will range from 3 - 4 mg/l. The D.O. concentration in the short-term aeration basin can be controlled by the operator. If there is not a great deal of variation in the food load throughout the day, the operator can hold the D.O. concentration in the aeration basin fairly constant. The best way to do this is to

hold about 0.5 to 1.0 mg/l residual D.O. in the short-term aeration basin during peak food load periods.

The respiration rate of the mixed liquor system is an important parameter for the control of the mixed liquor system. The procedure for running the "oxygen uptake rate" is in the 14th edition of Standard Methods. The respiration rate is a measure of how active the biological system is at any particular time. The units for the respiration rate (oxygen uptake rate) is mg O_2 per gram of MLVSS per hour. The parameters necessary to calculate the respiration rate are the time required to reduce the D.O. concentration in a mixed liquor sample and the VS concentration in the mixed liquor sample. Representative values can be acquired by using the spin test value for the solids concentration, but are for operational purposes only. This MLSS sample should be taken from the aeration basin. During peak food loads the respiration rate would be relatively high. The average respiration rate will probably be made in the range of 12 - 15 mg/l O_2 per gram of VSS per hour. A young sludge will have a higher rate than normal and an old sludge lower than normal.

The sludge blanket depth (SBD) in the secondary clarifiers is an important tool and the operator should utilize this tool frequently throughout the day. If the operator does not make any changes in the return sludge rate from the clarifier during the day, he will note that there will be a slight increase in SBD following the hydraulic increase during the diurnal flow pattern. As the plant continues to operate throughout the day, the sludge blanket will then lower again to a normal level as the diurnal flow pattern decreases. The return sludge concentration will increase, which removes more return sludge per unit volume at this time. By using the SBD and the settled sludge volume the operator will get an early warning of a bulking sludge or possibly a young biological system caused by too much food or excess wasting from the system. If the wastewater plant is subject to infiltration problems, the SBD will change because of the hydraulic loading entering the plant. If the return sludge rate is not increased during higher loading due to infiltration, most of

the solids will migrate to the clarifier. The operator, under these conditions, should increase the return sludge rate to remove the solids from the clarifier more rapidly. By continuing to monitor the SBD, the operator can control the SBD by increasing the clarifier return sludge rate so that the solids will not build up in the secondary clarifier.

The mixed liquor system is a mixed culture of several kinds of microorganisms. Not only are there several kinds of bacteria present, there are also other organics such as fungi, algae, protozoa, rotifers, and even a few crustaceans present.

The relative preponderance of the protozoan population is an indication of the condition of the mixed liquor system. This requires a microscopic evaluation of the mixed liquor on a day-to-day basis. A microscope with 400 power capabilities will suffice for this examination. The use of the microscope is an operational tool and will help the operator to correctly identify possible changes in the system. The biological population in the mixed liquor system is difficult to quantify and is usually used for relative numbers of various types of protozoans from day to day. The microscope is used with other operational criteria, such as appearance of floc during the settleometer test, settling characteristics, and general appearance of the mixed liquor and return sludge system.

When the mixed liquor is in good condition, there is a preponderance of stalked ciliates present in the mixed liquor. The stalked ciliates appear in clumps with attached stalks and look something like Russian thistles. There will be a few rotifers and free-swimming ciliates present also.

If for some reason the mixed liquor condition begins to deteriorate, the first visual observation seen is the disappearance of the rotifers and a reduction in the number of stalked ciliates. The free-swimming ciliates will now be the most common form seen. As the mixed liquor grows worse, the operator will begin to see that flocculation will become poor with continued reduction of stalked ciliates with free-swimmers most predominant.

If the mixed liquor degenerates further, the operator will note that his settleability will be poor with a cloudy supernatant. Microscopic examination under these conditions will reveal few or no stalked ciliates and free-swimming ciliates under the microscope. As mixed liquor conditions improve, the population trends reverse.

REFERENCES

1. "Full-Scale Evaluation of Activated Bio-Filter Wastewater Treatment Process." M and I, Inc., Fort Collins, Colorado, 1980, draft report for EPA research grant # R-806047-010.

2. "Owner's Manual for Neptune Microfloc ABF Systems." Neptune Microfloc, Inc., Corvallis, Oregon, 1979.

3. "Survey of Plants Operating Activated Biofilters/Activated Sludge." John R. Harrison, CH_2M-Hill, Inc., Corvallis, Oregon, 1980.

THE ABF SYSTEM

Worksheet #1

1. The reactor wet well:

_____ a. is a pumping station
_____ b. has fixed film growth
_____ c. collects only final effluent
_____ d. is a settling basin

2. Increases in bacterial populations can be measured as:

_____ a. increased flow
_____ b. higher influent BOD
_____ c. increased mixed liquor suspended solids
_____ d. increased D.O.

3. The reactor is:

_____ a. the area where suspended growth organisms are growing
_____ b. essentially a settling basin
_____ c. where the return sludge is collected
_____ d. the fixed film portion of the ABF system

4. Fixed film bacteria utilize the food from:

_____ a. the waste stream
_____ b. the final effluent
_____ c. the return sludge
_____ d. the settling basin

5. Oxygen transfer in the ABF system is a result of:

_____ a. air provided by a blower
_____ b. splashing action
_____ c. settling sludge
_____ d. fluctuating flow

6. ABF mixed liquor is composed of:

_____ a. raw influent and final effluent
_____ b. fixed film organisms
_____ c. suspended growth and sloughed fixed film organisms
_____ d. only suspended growth organisms

7. These organisms:

_____ a. must be wasted
_____ b. absorb, oxidize and metabolize organic food
_____ c. increase the BOD in the waste stream
_____ d. are nuisance organisms

8. Material is spread over the surface of the ABF media by:

_____ a. blowers
_____ b. fixed or rotary distribution systems
_____ c. ponding
_____ d. settling

9. An alternate process mode has the:

_____ a. reactor effluent going directly to the secondary clarifier
_____ b. sludge all returned to the head works of the plant
_____ c. sludge wasted in total
_____ d. return sludge wasted

10. The ABF system can be operated:

_____ a. like a high rate trickling filter followed by short term aeration
_____ b. without sludge return
_____ c. without influent BOD as food
_____ d. at 100% efficiency

11. When the ABF system is used as a roughing filter:

_____ a. sludge is not returned
_____ b. there is no tower reactor
_____ c. the reactor wet well is by-passed
_____ d. there is no aeration in the cycle

THE ABF SYSTEM

Worksheet #2

1. F/M ratio stands for:

   _____ a. flow and management ratio
   _____ b. flow to mass ratio
   _____ c. food to microorganism ratio
   _____ d. force to measure ratio

2. MCRT stands for:

   _____ a. mean cell retention time
   _____ b. mass concentration return time
   _____ c. mixed liquor concentration return time
   _____ d. microorganism concentration respiration transport

3. In the ABF system, the F/M ratio usually is in excess of:

   _____ a. 0.1
   _____ b. 1.0
   _____ c. 10.0
   _____ d. 0.01

4. MCRT in the ABF system is usually:

   _____ a. 1.5 to 3 days
   _____ b. 15 to 30 days
   _____ c. 0.15 to 0.3 days
   _____ d. 30 to 45 days

5. Given the following data for an ABF plant calculate the F/M ratio.

Avg. Flow	=	1 MGD
Primary Eff. BOD	=	150 mg/l
MLSS	=	3,500 mg/l
MLVSS	=	2,800 mg/l
Aeration Volume	=	0.045 MG

   _____ a. 0.019
   _____ b. 0.19
   _____ c. 1.19
   _____ d. 2.19

6. Using the data in problem 5, calculate waste sludge volume:

_____ a. 4,955 gpd
_____ b. 5,955 gpd
_____ c. 6,955 gpd
_____ d. 7,955 gpd

7. Using the same data, calculate MCRT.

_____ a. 0.26 days
_____ b. 1.26 days
_____ c. 2.26 days
_____ d. 3.26 days

8. The normal range for the MCRT in the short-term aeration basin of an ABF system is between:

_____ a. 0.15 to 0.3 days
_____ b. 1.5 to 3.0 days
_____ c. 3.0 to 4.5 days
_____ d. 15 to 30 days

9. The odor of ABF mixed liquor is:

_____ a. stronger than conventional A.S.
_____ b. fainter than conventional A.S.
_____ c. the same as conventional A.S.
_____ d. none of the above